MaarVLS: A Database of Maar Caters on Earth to Enable Investigation of Maars on Mars.

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Introduction: A maar crater is a negative landform recording explosive interactions between rising magma and subsurface water or ice. Maar craters are surrounded by low angle tephra rings made of layered ejecta. They are the product of tens to thousands of discrete explosions in a debris-filled vent, or diatreme [1]. A new database of Quaternary maar crater shapes, including diameter, aspect ratio, depth, distribution, and age, enables the global characterization of the distinctive characteristics of maar craters on Earth (n=163). This database is an important step to be able to remotely identify maar craters on Earth and other bodies, such as Mars.

The combined history of volcanic activity, liquid and frozen water in, and on, the surface of Mars makes it likely that maar type volcanic structures would be present. Previous studies of martian volcanoes have used a handful of well recognized maars and tuff cones on Earth for comparisons with candidate hydrovolcanic features [2], however, this approach will be limited as long as our understanding of maar craters remains limited on Earth.

It is first necessary to quantitatively establish what are the characteristic morphologies of unequivocal maar craters on Earth before comparing them with Martian features. The Maar Volcano Location and Shape (MaarVLS) database contains 163 craters that were manually outlined using visibile imagery from Google Earth and the Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) instrument. Maar caters included in the database have complete rims, are recognized in the literature as maars, are Quaternary in age, and have readily available imagery. An additional 100 craters have been selected as candidates for remote identification on Earth using this database. After testing remote identification of maar craters on Earth, the investigation will move to Mars to locate candidate martian maars.

Maars on Earth: Quaternary maar craters on Earth are typically between 0.6 and 1.0 km in diameter, with <10 % of craters with diameters 3.0-5.0 km (Fig. 1). The craters cut into the underlying geology and have depth to diameter ratios around 0.1. Although small maar craters are found at all latitudes on Earth, the maximum size for craters increases with laitutude, where the largest (>3.0 km) craters occur predominantly above 40 degrees (Fig. 2). These largest craters fall into two categories: permafrost-hosted craters and polygenetic craters. The well-known Espenberg maars on the Seward Peninsula [3] and Pali Aike maars in Argentina [4] both include craters greater than 3 km in diameter that are thought to have formed through permafrost. The other >3 km maars occur in the Colli Albani volcanic field and show evidence of multiple eruption deposits separated by paleosols [5]. In the database, all craters with evidence of multiple eruptive episodes separated in time (i.e. polygenetic) are greater than 1 km, but not all large craters show evidence for multiple eruptive episodes. The tephra rings of the Espenberg maars, for instance, appear complete and lack any evidence of soil development between eruptive episodes [3].

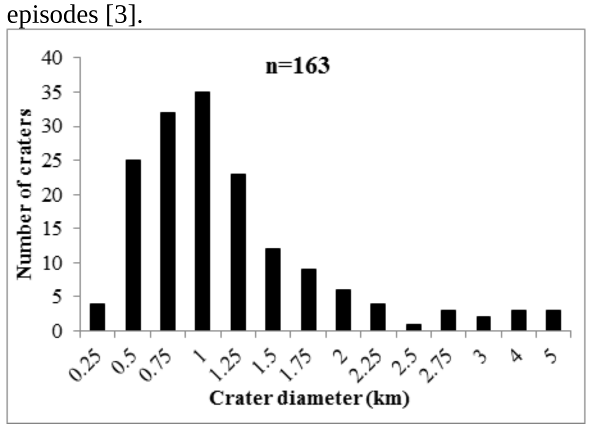

Figure 1: Average maar diameter (km) on Earth from MaarVLS database.

Maar craters are found in 1) monogenetic fields with similar sized volcanic features such as scoria cones, 2) in complex volcanic fields containing small volcanic vents in addition to larger structures such as stratovolcanoes and calderas, and 3) rarely in isolation. Over 92% of craters in the database occur in fields with other maars, where 65% of those craters occurred in fields with more than five maars.

Additionally, maar crater shape is revealed to be persistent over a range of timescales. Investigations of maar crater modification from the 1977 eruption of Ukinrek in Alaska revealed a rapid increase in crater diameter and infill of the crater floor in the decades after the eruption [6], but the shape of the crater, as measured by aspect ratio, was maintained. Comparison of aspect ratio and other shape parameters (elongation, isoperimetric circularity) for maars in the MaarVLS database with age indicate that there is no trend in crater shape modification with age for Quaternary maars (Fig. 3). These data provide characteristic shape parameters and contextural information that will be used to identify maar craters remotely on Earth and Mars.

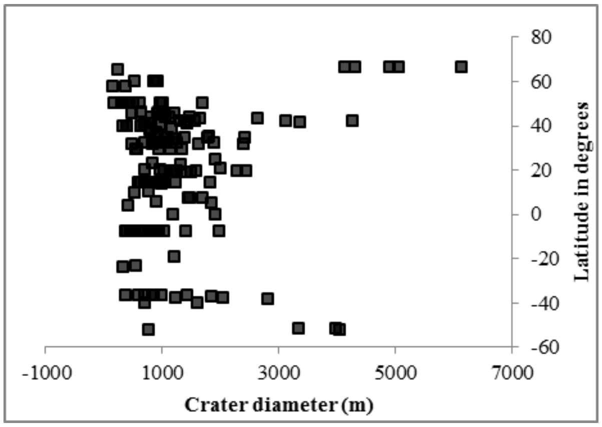

Figure 2. Maximum maar crater diameter by as a function of latitude on Earth.

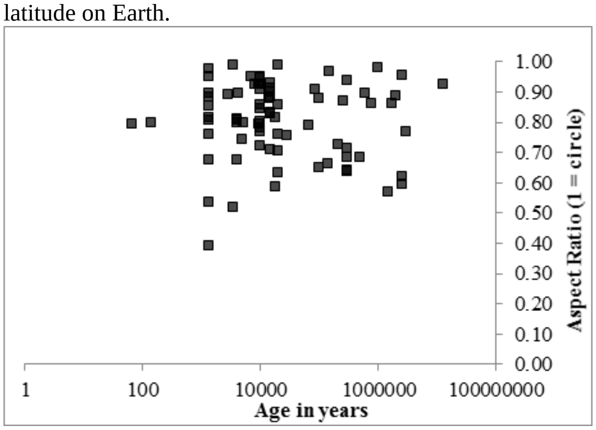

Figure 3. Aspect ratio of maar craters (short axis/long axis) does not appear to vary systematically with age.

Maars on Mars: The size and shape of maar craters in the database can be used to roughly estimate the size and shape of potential martian maar craters. Crater size is predominantly influenced by resisting forces (gravity, host rock cohesion, depth where explosions occur within the debris-filled vent) and the energy of the explosion [7, 8]. Therefore, it is reasonable to assume maar craters would be larger on Mars as a result of the reduced gravity, and to a lesser degree the thinner atmosphere. However, collapse processes are important to final crater shape and may be diminished in martian conditions, reducing the potential increase in martian maar crater diameter. Also, maar craters frequently experience lateral vent migration which produces complicated shapes of coalesced craters and contrubes to crater diameter [9, 10]. This growth of craters by lateral migration limits our ability to precisely constrain anticiapated martian maar crater sizes, but it would reasonable to assume they could range from 1-10 km in diameter and may have rare examples closer to 15 km.

Furthermore, maar craters must be differentiated from other similar features, in particular impact craters. I compared Martian impact craters (1-10 km in diameter) [11] with the MaarVLS database to quantify the difference between the two features. On average, maar craters have greater elongation, as represented by aspect ratio, than impact craters (Fig. 4).

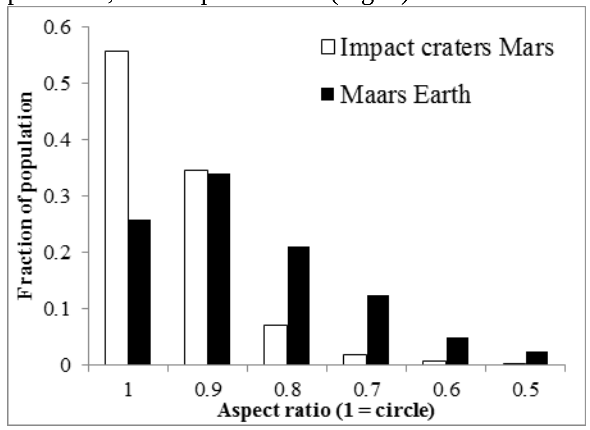

Figure 4. Aspect ratio of maar craters on Earth compared with impact craters on Mars.

Maar craters are elongate on average, and can display coalesced shapes, however, round maar craters will be still be very difficitul to distinguish from impact craters. Therefore, to recognize maar craters on Mars the preliminary investigations will focus on unique characterstics of maar crater size, shape, and distribution. Recognizable martian maar craters are anticipated to be found within larger volcanic fields, particularly with other maar craters, show elongate and coalesced shapes and be between 1-10 km in diameter.

The search begins: After testing remote maar crater idenficiation on Earth using the MaarVLS database these characteristics will be used to identify candidate maar craters on Mars. As larger maar craters have been found on Earth in permafrost environments preliminary locations for investigation are the Northern Polar Regions on Mars where subsurface magma water interaction are likely [12] and the resulting craters should be large enough to be recognizable [13, 14].

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